On the Viscosity of the Uranium Hexafluoride

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The viscosity and Sutherland's constant of the uranium hexafluoride were measured with the Maxwell type viscosimeter. The sample of the uranium hexafluoride was obtained by the reaction of fluorine gas on the uranium carbide, and the fluoride obtained was purified by the sublimations under the room temperature repeated several times. The first two sublimation processes were carried out through the dehydration tube which was charged with resublimed phosphorus pentoxide. The purified sample became colorless and clear crystals having a vapor pressure expressed by the following formula,

$$\log P_{UF_6}(\text{mm.Hg}) = 10.023 - 2486/T + 0.0012\,T, \qquad (1)$$

where T is absolute temperature. The measurements of vapor pressure were performed by a statical method at the temperature interval between 0° and 34.6°.

Apparatus

An oscillating-disk viscosimeter⁽¹⁾ with gold plated copper disks was used. An oscillating disk having a diameter of 30 mm. and thickness of 2 mm. was placed between two fixed disks. The distance between inner surfaces of the two fixed disks was 3 mm. The oscillating disk was adjusted to a place at the middle of these disks, and the distances which separate the oscillating disk and upper and lower fixed disks were kept equal 1.0 mm. The oscillating disk was suspended by platinum wire, of which the length about 20 cm. and diameter 0.05 mm. A thick copper wire of about 5 cm. length was used for the connection of the platinum wire and the oscillating disk. At the top of this copper wire a small mirror was cemmented. These metal works were contained in the quartz glass tube with a quartz glass window. All these apparatus were immersed in a thermostat. Amplitudes of succesive oscillations were observed by means of a telescope with cross hair, with the aid of an illuminated scale.

Method of the Determination of Viscosity

The fundamental equation for the oscillating-disk viscosity apparatus is

$$\eta = (\lambda - \kappa)/Kt, \qquad (2)$$

where η = viscosity, λ = logarithmic decrement, κ = logarithmic decrement caused by wire and mirror, t = period of one oscillation, in seconds, and K = the apparatus costant. The correction for end effect and slipping coefficient at the metal surfaces can be neglected in this case.⁽²⁾ We can obtain the logarithmic decrement λ with the following formula,

$$\ln(a_\nu - b_\nu) - \ln(a_{\nu+n} - b_{\nu+n}) = n\lambda\varphi \qquad (3),$$

where a_ν and b_ν are the successive observations of the amplitudes of left and right sides of an oscillation. Suffixes of ν and $n+\nu$ mean the observations about the ν- and $n+\nu$-th oscillations respectively. The period of one oscillation t (=16.03 sec. in this apparatus) was constant throughout the observations, then the equation (2) may be written as follows,

$$\eta = H(\lambda - \kappa), \qquad (3)'$$

where H is an apparatus constant. The constant κ and H were obtained from the following observations.

A main part of the logarithmic decrement κ is derived from the energy losses in platinum wire. The friction of mirror has a small contribution on κ⁽²⁾ therefore we may neglect it and take κ as a wire constant. To obtain the wire constant the logarithmic decrement was measured under the high vacuum. A series of six observations of a_ν, and b_ν with $n=30$ were performed in each determination. The average of κ was 0.000728 and each value agreed to within 1 per cent. The apparatus constant H was determined by logarithmic decrement with air at temperature 15.2°. The averaged value was $\lambda = 0.010667$. When we take the viscosity of air as $\eta = 179.62\ \mu$ poises,⁽³⁾ the constant H may be derived as $H = \eta/(\lambda-\kappa) = 18073 \times 10^{-6}$.

To check the apparatus, the viscosity of hydrogen was measured at temperature 12.9°. The observed value was $\eta = 86.7\ \mu$ poises, which agreed well with published values.⁽³⁾ There was no great change in apparatus constant with temperature variation, since the measurements with air at temperature 40.5° and 15.2° gave probable value of Sutherland's constants for air. The observed values of λ was 0.011321 at temperature 40.5°, and Sutherland's constant $S=104$ was obtained from these values. Hydrogen used in this experiment was obtained by electrolysis and purified through heated tube filled with platinized asbestos and a trap cooled with liquid oxygen. Dry air was purified through concentrated sodium hydroxide solution and a trap cooled with liquid oxygen.

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(2) G. E. MacWood, *Physica*, **V**, No. 5, 374, 763 (1938).

(3) H. L. Lohnston and K. E. McCloskey, *J. Phys. Chem.*, **44**, 1053 (1940).

The observations using these gases were performed under an atmospheric pressure.

Viscosity of the Uranium Hexafluoride

Preliminarily, highly evacuated apparatus was filled with uranium hexafluoride by sublimation from the container of UF_6 crystals. The viscosities were measured at approximate 10° intervals from 14.5° to 44.7°. The observed values of λ and η are shown in Table 1. The sample for the observations at the temperature 14.5° was filled by the sublimation under 8°. For the observations at the temperature higher than 20°, the sample was sublimed at 18°. Therefore in each case the pressure of uranium hexafluoride in apparatus was 33 mm.Hg and 68 mm.Hg respectively. The measurements of logarithmic decrements taking the series of eleven observations of a_ν and b_ν with $n=5$ (*e. g.* $\nu=10, 15, 20\ldots 70$) agreed to within 0.2 per cent.

Table 1

t°C.	λ	μ poises (obs.)	μ poises (calc.)
14.5	0.00973	162.7×10^{-6}	162.4×10^{-6}
26.3	0.01013	169.9 〃	170.1 〃
35.2	0.01045	175.7 〃	176.0 〃
44.7	0.01083	182.5 〃	182.2 〃

The Sutherland's formula,

$$\eta=CT^{3/2}/(T+S) \qquad (4)$$

can be fitted to the observed values using the following numerical constants:

$$C=28.44\times10^{-6}, \qquad S=566.8$$

The calculated values from these expression are shown in Table 1.

By the use of the following formula,

$$C=\frac{5}{16\,\sigma^2}\left(\frac{km}{\pi}\right)^{\frac{1}{2}}, \qquad (5)$$

where k = Boltzmann constant, σ = molecular diameter, m = mass of the molecule, we can obtain the molecular diameter of uranium hexafluoride.

$$\sigma=4.20\,\text{Å}.$$

When we assume that the observed viscosities are proportional to T^s, then $s=1.16$ in this case. The rigidity ν of the molecule given by $s=1/2+2/(\nu-1)$ is obtained for uranium hexafluoride as $\nu=4.03$.

Summary

On the uranium hexafluoride obtained by the reaction between fluorine and uranium carbide, the viscosity was measured between 14.5° and 44.7°. The purification of uranium hexafluoride was performed by several repeated sublimation. The oscillating-disk viscosimeter was used in this experiments and its apparatus constant was obtained by the observation of the apparatus filled with air. The molecular diameter of uranium hexafluoride was determined from the Sutherland's constant, and the rigidity of the molecule was also obtained from the observed values.

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